UNIVERSITY OF MINNESOTA
Minnesota Geological Survey

Riverbank collapse in northwestern Minnesota: an overview of vulnerable earth materials

Summary

The slumping along the Red River and its tributaries in northwestern Minnesota, such as the 2003 incident at Crookston, is a natural result of river erosion and the presence of slump-prone clay deposits. The best defense against the loss of property and infrastructure is to identify vulnerable sites and avoid building in these areas. A better awareness of the problem can be gained through geological mapping of at-risk areas and making the information widely available.

Introduction

Bank-failure problems are caused by gravity acting on earth materials resting on a slope. In the case of failure, gravitational forces exceed the forces holding the sediment together. Failures can take several forms depending on sediment type, sediment layering, and moisture content. Red River Valley bank failures are typically the result of slumping (Figs. 1 and 2; Baracos and Render, 1982; Baracos and Kingerski, 1998; Schwert, 2003) in which a block of earth moves downward along a curved failure plane, commonly with a backward rotation of the slump block. The fundamental reason why deposits in this area rupture and sag is because they consist of clay rather than sand, silt, or gravel.

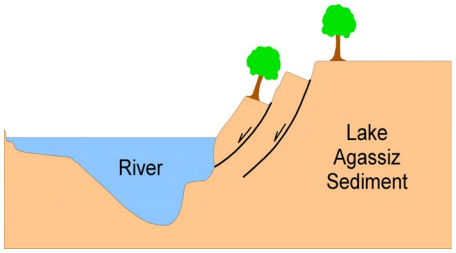

Figure 1. Diagram showing rotational slumping on a curved failure plane (modified from Schwert, 2003).

Clays are present in northwestern Minnesota because the Red River Valley is the floor of ancient Glacial Lake Agassiz—a large lake that formed at the edge of a retreating Ice-Age glacier (Clayton and Moran, 1982; Fenton and others, 1983). Both glacial and lake sediments were deposited and these clays are exposed along the rivers of the Red River Valley (Schwert, 2003). Riverbanks particularly vulnerable to slumping are those that consist of an upper, relatively competent layer of sediment called the Sherack Formation resting on more easily deformable clays of the Huot and Brenna Formations (Harris and others, 1974).

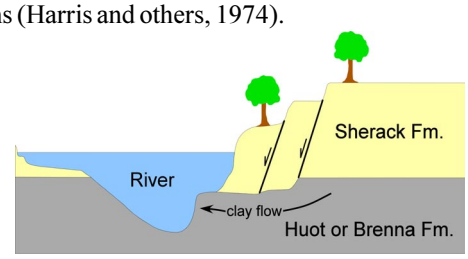

Figure 2. Diagram showing vertical movement of slump blocks as viscous clay flows in response to stress (modified from Schwert, 2003).

Slump-prone Deposits

The Sherack Formation (Fig. 3; Harris and others, 1974) is the surface sediment in most of the Red River Valley. It was deposited offshore in Lake Agassiz and consists of laminated clay, sand, and silt about 25 to 30 feet thick. The Sherack Formation is clayey in the central Red River Valley; it thins and becomes sandier towards the eastern and western margins of the lake plain. The Sherack Fm. is about 8 to 10 feet thick in the Crookston area. Depending on location, the Sherack Formation overlies either the Huot, the Falconer (a lateral equivalent of the Huot), or the Brenna Formation, or older deposits (Arndt, 1977). It forms a compact relatively competent surface layer, but is subject to block failure if the underlying clay is exposed (Fig. 2).

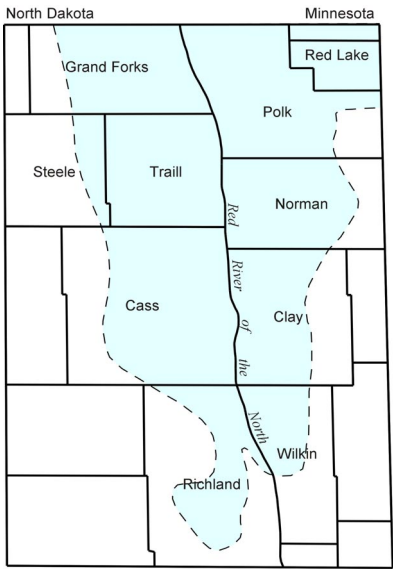

Figure 3. Approximate area where the Sherack Formation is present.

The Brenna Formation (Fig. 4; Harris and others, 1974) was also deposited offshore in Lake Agassiz. The Brenna is 60 to 95 percent clay (Arndt, 1977) that has a high natural water content, very low shear strength, and flows when subjected to stress. It is present north and south of the Edinburg moraine, which marks the southern extent of the Huot Formation (Fig. 4; Arndt, 1977). Brenna is overlain by the Sherack Formation and isolated river deposits. It overlies the Falconer Formation north of the Edinburg moraine and older Lake Agassiz sediments south of the moraine. It is not present in the Crookston area, but is responsible for bank-stability problems elsewhere.

The Huot Formation (Fig. 4; Harris and others, 1974) is a glacial sediment that consists of unbedded slightly pebbly clay. The Huot underlies the Sherack Formation in the Crookston area and is exposed at the surface in the Edinburg moraine. It overlies older Lake Agassiz sediment. It was deposited along the margin of a glacier that moved south in the Red River lowland to the Shelly, Minnesota area, formed the Edinburg moraine, and then retreated. The Huot is extremely clayey for glacial sediment—62-84 percent clay (Arndt, 1977). The glacial ice that deposited it flowed into Lake Agassiz,

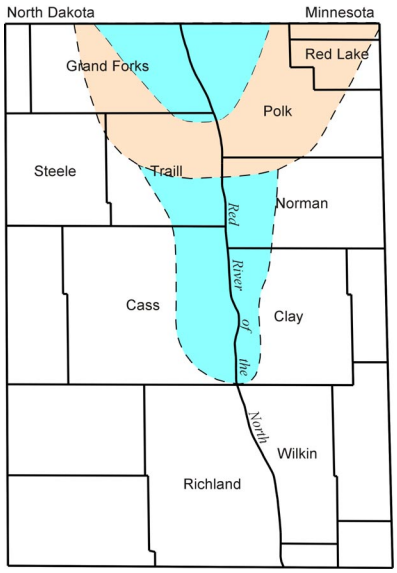

Figure 4. Approximate area where the Huot (brown) and Brenna (blue) Formations are present beneath the Sherack Formation. The depicted Huot extent makes up the Edinburg moraine.

eroding and redepositing lake sediment. The clay has a high natural water content, very low shear strength, and flows when subjected to stress. The Huot is the unit responsible for bank instability problems in the Crookston area.

Slump-prone Areas

These sediments have been eroded by the rivers that flow across the Lake Agassiz clay plain. When a river valley erodes through the Sherack it exposes the underlying clay of the Huot or Brenna Formation and a potential slump situation is created. Various processes affect the actual mechanism of failure in vulnerable deposits. For example, cracks that form in the surface sediment from normal wetting and drying cycles create planes of weakness in the Sherack Formation. These cracks tend to form parallel to river valleys as the sediment settles near the valley wall. As gravity acts on the sediment blocks it stresses the underlying clay. If the resulting shear stress exceeds the shear strength of the underlying clay, the block slides down the failure plane towards the river. Human activity can exacerbate this process. Houses and roads built too close to the river bank create additional loading on the blocks, increasing the risk of bank failure.

These conditions are present throughout the Red River Valley from Lake Winnipeg to south of Fargo (Arndt and Moran, 1974; Baracos and Render, 1982; Baracos and Kingerski, 1998; Schwert, 2003). The Huot Formation is present in the Edinburg moraine and it underlies the Sherack Formation in the Red Lake River valley. It's distribution in the area extending north of the moraine to the Canadian border has not yet been mapped. The Brenna Formation is present north and south of the Edinburg moraine where it underlies the Sherack Formation. The bank failure scenario is the same whether it is the Huot or the Brenna Formation underling the Sherack Formation.

Where we locate our houses, businesses, and roads is important economically, environmentally, and emotionally. The losses suffered by individuals and government through natural disasters are tremendous, and not always avoidable. However, development of enhanced guidelines supported by required information such as more detailed geological mapping will help us avoid future losses.

Recommended References

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Schwert, D.P., 2003, A geologist's perspective on the Red River of the North: history, geography, and planning/ management issues. Proceedings 1st International Water Conference, Red River Basin Institute, Moorhead, MN.

Some useful websites

-Minnesota Geological Survey:
www.geo.umn.edu/mgs
-Environmental problems in the Fargo, ND area:
www.ndsu.nodak.edu/fargo_geology/
-General discussion of various forms of mass movement:
www.landau-forte.org.uk/geography/geomorphic.htm
-General discussion of various forms of mass movement:
www3.interscience.wiley.com:8100/legacy/college/skinner/0471152285/ppt/ch13.ppt

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